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AB 1007 Full Fuel Cycle Analysis (FFCA) Peer Review

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AB 1007 Full Fuel Cycle Analysis (FFCA) Peer Review

Introduction

LLNL is a participant of California's Advanced Energy Pathways (AEP) team funded by DOE (NETL). At the AEP technical review meeting on November 9, 2006 The AB 1007 FFCA team (Appendix A) requested LLNL participate in a peer review of the FFCA reports. The primary contact at the CEC was McKinley Addy. The following reports/presentations were received by LLNL.

- Full Fuel Cycle Energy and Emissions Assumptions dated September 2006, TIAX
- Full Fuel cycle Assessment-Well to Tank Energy Inputs, Emissions, and Water Impacts dated December 2006, TIAX
- Full Fuel Cycle Analysis Assessment dated October 12, 2006, TIAX

Documents were received by LLNL late December 2006 and provided to reviewers January 4, 2007. A cursory review funded by LLNL was completed. The LLNL reviewers were Dave Rice, Alan Lamont, Chris Campbell, Dave Armstrong, Ravi Upadhye, Gretchen Gallegos and Jeff Stewart. Biographies are provided in Appendix B.

A peer review meeting was held on January 9 at Sacramento and Livermore via WebEX. Attendees at LLNL included Jeff Stewart, Dave Rice, Alan Lamont, Ravi Upadhye, Nalu Kaahaaina, Annette Macintyre (LLNL) and Steven Unnasch and Michael Hooks (TIAX). The Agenda is provided in Appendix C. TIAX took extensive notes of reviewers' comments. Copies of the TIAX record and a summary by McKinley were reviewed subsequent to the meeting.

Purpose and Scope

McKinley Addy provided the following guidance, along with the Agenda (appendix C).

"The general topics we (FFCA) want to cover although we expect to prioritize them, and perhaps prune the list by the time of the meeting:

- Vehicle emissions
- Fuel economy
- Production issues for specific fuels
- Agricultural impacts related to ethanol and biodiesel production
- Petroleum refinery impacts
- Synthetic fuels and Hydrogen
- Electric Power Generation
- Criteria Pollutant assumptions for fuel production equipment
- TIAX's California Post Processor Use in the FFCA (The CA Post Processor is TIAX's modified version of GREET treating CA conditions not in the general GREET model.)
- Treatment and presentation of the FFCA assumptions
- General modeling approach

We would also want the peer reviewers to think about the top three to five issues the FFCA should address.

We want to get feedback on consensus items and point out areas of differences/gaps or possible controversy and how to deal with them.”

According to McKinley, AB 1007 requires the Energy Commission, working with the Air Resources Board to develop a plan to increase the use of alternative fuels in California. The legislation directs the Energy Commission to conduct a Full Fuel Cycle Analysis of the alternative fuels proposed in the plan, and to insure that there is “no net material increase in emissions” from the increased use of such fuels.

LLNL provided reviewers with expertise in energy economics, chemical engineering, environmental science and environmental engineering. The GREET model was not provided and not reviewed. The Well-to-Wheel report was not provided and not reviewed. Due to time and funding constraints the reviewers spent 4-8 hours reviewing the main report, Full Fuel cycle Assessment-Well to Tank Energy Inputs, Emissions, and Water Impacts dated December 2006, TIAX

Summary Comments

Principal concerns of the reviewers were the treatment of uncertainty through out the analysis, the ostentatiously absent analysis of water and other non-air impacts. Concern was also expressed about the minimal discussion on biodiesel and nuclear power generation. It was noted that non-carcinogenic hazards weren’t addressed not were developing advanced technologies.

All reviewers felt a concise summary that would include the intended use of the analysis was necessary. In general more caveats need to be included and assumptions laid out clearly.

Reviewers’ Comments

Dave Rice

This report is intended to provide information to help California energy decision makers understand the consequences of energy choices on environmental emissions through out the fuel source life cycle. While a stated goal of this report is to evaluate total fuel cycle emissions, the report focuses primarily on air emissions and does not adequately address emissions to other environmental media such as soil or water resources, and therefore, does not provide energy decision makers adequate information to allow informed choices regarding the impacts to water resources and environmental media other than air. Further, this report does not adequately address waste streams that may be generated as a result of energy choices.

Water resources are critical to California and may be an important limiting factor in the economic and population growth in the future. Additionally, water and energy are

closely linked both as a feedstock and process resource and for energy production cooling. Further, increased fertilizer, pesticide, and herbicide impacts to water resources during biomass production may be critical.

This report uses many simplifying assumptions. There is a danger that decision makers may carry the result to levels of detail that are not justified. The devil is in the details for specific fuels, particularly with regard to emissions to surface and subsurface environments.

The report needs to more explicitly address the uncertainty involved in this analysis.

Recommended adjustments:

A specific chapter on uncertainty is needed. The uncertainty associated with key decision making factors needs to be identified, addressed, and discussed. Identify key driving issues and uncertainties. Rate limiting factors and knowledge gaps need to be identified. For example, lack of knowledge of the environmental behavior of released chemicals, the availability of rare earths and other raw materials, public acceptance issues such as odor, regulatory approval processes.

There needs to be a discussion regarding the appropriate use of this report. State plainly that simplifying assumptions do not allow specific fuel decisions. This report may be useful in making broad energy input and air impact comparisons for general fuel types or classes but this report cannot be used to make specific fuel related decisions. For example, the issue of the environmental impact of transportation fuel additives is not addressed and the environmental consequence of additive choices has proven to be very important to energy decision-making.

Expand the analysis for water impacts. In addition to releases to water resources and water demands during normal operations, release scenarios (failure modes) through out fuel life cycle for each fuel option or class of options needs to be developed. Identify and compare most likely and most hazardous scenarios across various fuel options. The ability of available environmental risk management strategies to address potential releases may be an important consideration in fuel decision-making. Alternatively, a disclaimer needs to be added to the beginning of the document to make clear that environmental media other than air are not fully considered and the reasons why this has been done.

Clarify to the reader the release media referred to whenever the word “emissions” is used. Care must be taken to specifically identify which type of emission is being considered. In most cases through out this report the term “emissions” refers to only air emissions.

A specific chapter on waste streams is needed. This chapter would deal with additional hazardous materials or new waste streams may result as a consequence of energy decisions. Thermal emissions associated with various energy options are not considered and a chapter on waste streams may be a place to discuss thermal emissions during

energy production. This may also be and place to discuss the important impacts of increased use of fertilizers, pesticides, and herbicides during biomass production.

Note on the TIAX record of Peer Review discussion: TIAX did a very good job capturing comments in a rapid fire discussion. One note: the problem addressed by adding biocides to biodiesel is not that the microbes will rot or damage the tank, but that the quality of fuel is degraded when the microbes grow in the fuel and the microbial biomass fouls the fuel system. If there is also water present, then clogging precipitates are also formed.

CEC summary:

Dave Armstrong

1. I checked several of the specific emission factors used in the report and they appeared to be correct and appropriate. I believe that the emphasis on using South Coast regulations is appropriate, because the other larger air districts seem to be following the lead of South Coast in many instances. This also helps to simplify the analysis.

2. I noted that the reports focus on motor vehicles as the ultimate use of the fuels. I wonder if there should be some more discussion about fuel usage and air emissions from boats, ships, trains, electric generators, heaters, power tools, etc.

3. The reports provide a more in depth analysis of environmental pollution from gasoline refining, than for alternative fuels. For example, in the Assessment Report, page 131, Table 6-1, there should be more analysis and data for the alternative fuels. Biodiesel should have some losses to the environment of methanol, not just hexane. Ethanol manufacture may have additional toxic air emissions, such as formaldehyde, methanol, and acrolein, but these are not listed. Both biodiesel and ethanol production are likely to have some impact to water, however, Table 6-1 indicates no impacts to water. (For example, nitrates, fertilizer and pesticide runoff from farms growing the feedstocks.)

4. It appears that the greatest deficiency of the reports is the lack of sufficient analysis and summarization of all of the well documented data. The reader wants to know "What is the fuel pathway for the future in terms of cost-effectiveness and impact on the environment" I could not find the answer to this question in my brief review. Also, I expected to see an extensive discussion of nuclear power generation impacts in association with hydrogen production, but I did not find that.

CEC Summary: I agree, except that the comments fail to capture one important general comment, i.e., that the report requires more analysis of the data and a clear summary of the analysis, with conclusions.

Gretchen Gallegos

I agree with your (Dave Rice) comments and have these of my own.

It definitely still has some big holes, e.g., there is virtually no information about biodiesel or effects on surface and ground water. There is at least some information available about nutrient runoff and corn/ethanol production and soybean/biodiesel production that could be included. The document is not consistent in handling information. It appears that there is a lot of detail about petroleum based products, and very spotty information on the other subjects. It is as though the authors knew about petroleum and did not do enough "digging" to develop a similar level of detail about the other energy sources.

As to health effects, I am not sure why they only looked at emissions that produce carcinogenic effects (see page 3-7). There are many materials in the list on table 3-4 that have significant potential for noncarcinogenic hazard, e.g. HF, lead and mercury. If those effects are not to be considered, they should at least provide some reason why not. I am also not sure what they are doing with the health effects data, i.e., how will it be compared across the energy sources. I may have missed it, but I did not see any health effects data for any other fuels.

What concerns me the most is that the purpose for this document is not clear. There is a lot of [to me, disjointed] information, but there are no conclusions drawn. I was hoping to see a matrix or table, perhaps normalized to 1000 miles driven, with personal vehicles, such as gasoline, hybrid, hydrogen, ethanol, diesel and biodiesel, and the associated production effects/emissions, transportation effects/emissions, energy costs, normalized health effects, etc., so that some comparisons could be made. A similar table could be made comparing diesel and biodiesel for large trucks.

Without some sort of summary, the reader is forced to become as familiar with all of the material as the authors.

CEC summary:

Chris Campbell

On AGRICULTURAL IMPACTS ETHANOL AND BIODIESEL

The water quantity and quality issues involved in the feedstock and refining are not well addressed.

On PETROLIUM REFINERY IMPACTS

There is not much direct data and modeling of the water quality impacts of refining in the Bay Area, however there is a lot of antidotal evidence. I remember a community group report on dioxins. Selenium is not mentioned at all, but it has been an issue local refineries are regulated on.

FFCA areas for TIAX

No Comments

Other Miscellaneous:

1. It appears misleading to list water impacts in the title when so little on the subject has been addressed. There is far greater analysis which could be performed here including:

- Comparison of water consumption in during hydrogen production (Steam or Auto thermal Reforming) to water consumption during petroleum refining,
- The important question of where more or less water would be requires under various alternatives, how that compares to current usage, and where would new water come from in CA,
- Washout of air pollutants including NO_x, SO_x, CO, PM_x, heavy metals, is only indirectly considered as a potential water quality problem, but could also be considered as a localized acid rain/fallout problem that can impact corrosion and deterioration of engineered structures, as well as human and environmental health,
- The air permit requirement for discharges to water mentioned on pg 1-2 are not discussed in Section 6. These would include Clean Water Act National Pollutant Discharge Elimination System (NPDES) Permits for all wastewater and storm water runoff discharges from refinery facilities. Most of these already exist. It is not obvious that there would be any different requirements for various alternatives other than upcoming regulation of agricultural drainage and further restrictions on nonpoint source pollution. However, the existing NPDES Permits for refineries might provide better data on environmental releases than the TRI (used in Section 6).

2.

In general the Toxics Release Inventory (TRI) is not an ideal source for modeling exercises. It does not require a facility to perform any additional monitoring, only report on values they already monitor (like through NPDES permits and chemical inventories).

3. There are a couple of assumptions in Section 3.11 that are potentially questionable, specifically that the proportion of nuclear and hydropower will remain similar to the current scenario. Is that what PG&E is projecting? The major nuclear power plants in CA will have had to go through re-licensing with the NRC by 2030 and have found a place to store spent fuel rods to maintain current production levels. The hydropower infrastructure is also aging and not without controversy. The assumption is likely OK given that we do not know exactly what will happen, but it should not be accepted without considering the potential future of these energy sources in the State.

4. Global warming is only lightly treated in relation to GHG. This is understandable given the enormity of the issue, however, no projections that involve water or air pollution in CA can be done without considering that water supplies may be more irregular and that different temperatures are important to the formation and dispersion of CO and other automobile emissions.

5. Why is hydrogen storage not considered in the same manner as the petroleum fuels?

Minor Comments:

- Many of the missing sections in 3.7.x are important for this discussion

- Table 2-2 the purpose and interpretation of this table is unclear. Is there supposed to be a scale for the “Analysis Metric” or are the divisions made arbitrary?
 - Is blank the correct symbol for nautical mile? I've seen NM or nm.
 - Table 2-9 the footnote for Chromium Compounds is missing
 - Pg 3-6 Second line of first paragraph there is a sentence fragment
- Pg 3-28 second paragraph is almost all repeated information (word for word)

CEC summary: I am OK with the comments (in the summary). I am still concerned at the inadequacy of the water issues addressed, which I guess are covered in the "Include environmental media..." comment. However, given that water is in the title, it should be more explicitly covered (i.e. water quality, water use, and water consumption).

Ravi Upadhye

A major omission in the report is a mention of advanced technologies that are currently being developed. For example, in the hydrogen production arena, high temperature Gen IV nuclear reactors are being designed to produce hydrogen by thermo-chemical splitting of water. Such a reactor may not materialize in the next 15 years, but is possible in the next 25 years. This would reduce the emissions due to hydrogen production by orders of magnitude.

Ethanol can be produced by both fermentation and by high-temperature processes (e.g., biomass gasification, followed by gas cleanup, water-gas shift reaction, and alcohol synthesis). The report needs to acknowledge this pathway for the sake of completeness.

Even though most of the methanol currently made is made from natural gas, technology exists to produce it from biomass. If this production path were to be significant, the net GHG emissions due to methanol production would be significantly lower than at the present time.

A comment was made regarding the high level of pollutants emitted when biomass is used in direct combustion boilers to produce electricity. However, if we gasify the biomass first, and then burn the product gas, the resultant emissions will be lower by significant margins.

References were made to a number of models. A brief section listing the models used, along with some reference providing detailed information regarding these models would be very useful.

Note on the TIAX record of Peer Review discussion:

CEC summary:

Alan Lamont

Projections of EVs are small

Between 1 and 2 million EVs are projected for 2030 (depending on assumptions about miles driven per year). CEC is forecasting something on the order of 30 million cars by 2020. The projected number of EVs is very small compared to this. This is a plausible case, given today's policies and fuel costs. If it is possible that EVs play a significant role in future carbon emissions reductions, then we would expect more vehicles than this. What would be the implications of a larger share of EVs?

Electric generation system impacts (section 3.10)

The report needs to state clearly that this section attempts to determine the marginal electric producer, since the emissions from the marginal producer will be the emissions that result from the introduction of alternative fuels.

The section concludes (see p 3-44 paragraph beginning "In this analysis ...") that the marginal producer will probably be a natural gas fired combined cycle combustion turbine (NG CCCT) along with renewables. This is probably correct, but the discussion of the section does not really support this conclusion. The section further concludes that the component of the marginal generation will likely be land fill gas fired simple cycle combustion turbines (SCCT) and wood/biomass fired steam turbines. In our review session, TIAX explained their reasoning for including renewables in the marginal generation. This is discussed below. Although the reasoning does argue that renewables should be included in the marginal generation, there is no support for the conclusion that it should be these particular types of renewables.

There is no explanation as to how Table 3-15 (p 3-41) was developed. While the generation levels shown in the table are plausible, this is highly speculative and subject to substantial uncertainty. The report could simply say that this is an example of a possible future development pattern. However, would the conclusions from the report be any different if the development pattern were different?

The representation of EV demands in figures 3-19 through 3-22 is hard to interpret. The figures show the EV charging load as if it were a supply. The discussion in the report focuses on *generation* (i.e. energy) from each type of generator rather than *capacity* (i.e. power). One needs to make a determination of the capacity of each type of generator in order to make an estimate of what the marginal generator will be.

The analysis estimates the hourly dispatch of various generators over different types of days (e.g. peak and non-peak days) (see figures 3-19 to 3-22). While the dispatch patterns shown are plausible, there is no explanation as to how they were developed. These must have been made with some sort of assumption about a) the capacities of different types of generators, and b) the merit dispatch order of the generators. In addition, a profile is shown for the dispatch of hydro over each day. The actual dispatch patterns depend on the availability of water stored and the value of the hydro electricity over the day. Again, the pattern shown is plausible, but it is not explained how it was derived. Finally, the renewables portion of the generation is shown as a nearly constant level of generation over each day. With substantial wind and some solar energy, this would not be true. Some days the wind will be strong, and some days it won't. This should be at least mentioned.

Determining the marginal generator out in year 2030 is somewhat difficult. The authors might be on more solid ground to just make a logical argument that CCCT would be the marginal generator during much of the day, provided that CCCTs are still a primary generator. The economic argument could be something along these lines: The marginal generator sets the marginal cost of electricity each hour, and in the long run it sets the marginal return to all the generators that are operating in each hour. Baseload generators will be on the marginal very few hours of the year. If they were on the margin many hours per year, the return to them would not be sufficient to cover their capital costs (since the marginal cost would just be their marginal operating cost). If there is enough renewable capacity to provide for the entire load over and above what the baseload generators can provide, then they *might* be the marginal generators, depending on their operating costs. If the renewable generation capacity is not sufficient to cover the entire load, then something else will be the marginal generator. The CCCT is the plausible type of generator to meet the load over and above what the base load and the renewables can meet. This line of argument leads to the conclusion that CCCT will usually be the marginal generator, which is the conclusion of the TIAX report. An argument like this is reasonably robust in that it does not depend on making specific projections about future capacities—it does rest on the assumption that renewable capacity is not likely to be large enough that it can be the marginal generator very many hours. TIAX can also explore the implications of having a large enough renewable capacity that it is marginal in a significant number of hours.

Note on the TIAX record of Peer Review discussion: I looked over TIAX's summary of the comments. It looks fine for my area.

CEC summary:

Appendix A: AB 1007 Core team members

Advanced Energy Pathways Team

Suzanne Phinney, California Energy Commission, sphinney@energy.state.ca.us

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Appendix B: Biographies

DAVID W. RICE

Environmental Scientist, Environmental Restoration Division, Lawrence Livermore National Laboratory, University of California, Livermore, California.

Mr. Rice is an expert on the fate and transport of contaminants in subsurface sediments, ground water, and the marine environment. He directed the preparation of the assessment of the environmental impacts of the use of ethanol as a fuel oxygenate in California and was the Project Director for the evaluation of multimedia impacts resulting from the use of PuriNOx fuel in California. He has directed the Chlorinated Volatile Organic Compound (CVOC) Historical Case Analysis Study, the Department of Defense Petroleum Hydrocarbon Cleanup Demonstration Program and was the lead scientist for a team of University of California collaborators assisting the State of California in re-evaluating leaking underground fuel tank cleanup decision-making processes. During his 30 years at Lawrence Livermore National Laboratory (LLNL), Mr. Rice has participated in the management of the LLNL superfund sites and directed and performed research on environmental decision-making, information management, and decision support systems for the optimization of environmental remediation. His research includes the application of risk-informed decision-making to environmental restoration activities, the life cycle environmental impacts of fuel choices, and cost/benefit analysis and multiple stakeholder interactions during environmental decision making. Mr. Rice has authored/co-authored over 60 publications.

JEFFREY STEWART

Environmental Economist, Systems and Decision Sciences Section, Engineering Directorate, Lawrence Livermore National Laboratory, University of California.

Mr. Stewart is an expert on Systems Analysis and Economic Modeling. He has led numerous research projects covering Environmental, Energy and National Security subjects. He is managing the LLNL Advanced Energy Pathways team and its effort to evaluate strategies to develop a Hydrogen Transportation System in California. Previous work includes leading a DOE effort to create an evaluation tool to recommend contaminant reduction strategies for Total Maximum Daily Loads (TMDLs) in U.S. waterways. This tool was developed to assist the EPA in developing its allocation reduction strategies for emitters. He also has led efforts to estimate uncertainty in clean up strategies at a Superfund site. Mr. Stewart is also leading several DOE efforts to evaluate technology options and costs for clean energy production. During his 10 years at LLNL, Mr. Stewart has been the Group Leader for the Applied Statistics and Economics Group, participated in numerous federal peer review efforts and authored/ co-authored over 20 publications.

ALAN D. LAMONT

Engineer, National Security Engineering Division, Lawrence Livermore National Laboratory, University of California, Livermore, California

Dr. Lamont is an expert in economic analysis of energy technologies and energy systems. He has developed specialized software for modeling energy systems and technologies. He has developed models of the Chinese energy system, and system in Japan. He has also developed economic analyses of future nuclear power technologies and conducted socio-economic analyses in support of license applications for nuclear facilities.

RAVI UPADHYE

Chemical Engineer, Chemistry, Materials and Life Sciences Directorate, Lawrence Livermore National Laboratory, University of California, Livermore, California. Dr. Upadhye's expertise is in the area of chemical process design, analysis and modeling. He has worked as a process engineer in private industry for ten years in the field of petrochemicals and coal. He joined the Laboratory twenty-two years ago. His experience at the Laboratory includes assignments in Uranium Enrichment, Underground Coal Gasification, Laser Fusion (NOVA as well as NIF), Mixed Waste Management Facility, Demilitarization of Conventional Munitions, Counter-proliferation Analysis, and Micro Fuel Cells, and Energy Systems. He has over 50 publications and conference presentations, and holds four US patents. Dr. Upadhye is a Registered Professional Engineer in Pennsylvania and California.

CHRIS CAMPBELL

Chris Campbell has been an Environmental Scientist at the Lawrence Livermore and Lawrence Berkeley National Laboratories since 2001. Chris currently works in the Water Guidance and Monitoring Group, but has worked on the Yucca Mountain Project and various research topics. His education includes a B.S., M.S., and Ph.D. in environmental sciences all from the University of California at Berkeley. Dr. Campbell has published more than 20 scientific papers and many quarterly and annual regulatory reports. He has been a member of the American Chemical Society, American Geophysical Union, Soil Science Society of America, American Water Resources Association, and a committee member for the Scientific Agenda Working Group of the California Storm Water Quality Task Force.

GRETCHEN GALLEGOS

Gretchen Gallegos is an environmental scientist (B.S. Biology, J.D. Santa Clara University), with 15 years of applied environmental monitoring and modeling experience at LLNL. She is currently the group leader for the Terrestrial and Atmospheric Monitoring and Modeling group and has been responsible for using U.S. EPA regulatory air dispersion models for determining LLNL compliance with radionuclide National Emissions Standards for Hazardous Air Pollutants (NESHAPs) and the National Environmental Policy Act (NEPA), and for surveillance monitoring of soils for LLNL. She has also conducted human health risk assessments in support of RCRA permitting and air permitting activities.

DAVID ARMSTRONG

David Armstrong is a Registered Civil Engineer (California) with over 35 years of experience in environmental engineering and management, including regulatory affairs. He holds a Masters of Science in Engineering, with a specialty in environmental engineering. For the last 20 years, he has been employed by the University of California at Lawrence Livermore National Laboratory (LLNL). His experience at the LLNL Environmental Protection Department has emphasized air emissions permitting and management, air emissions modeling, and pollution prevention. He is designated by the San Joaquin Valley Air Pollution Control District as a Certified Air Permitting Professional. Additional experience at LLNL included the areas of hazardous waste management and community right-to-know regulations. His experience prior to employment with LLNL included environmental consulting, environmental manager for a large industrial manufacturer, and staff engineer for a regional environmental regulatory agency.

Appendix C: Agenda

California Energy Commission and California Air Resources Board AB 1007 Project

AB 1007 Full Fuel Cycle Analysis Peer Review Meeting

January 9, 2007
9:00 AM to 1:00 PM

AGENDA

- I. Issues of importance the Peer Reviewers think the FFCA should address, gaps and how to close such gaps (Each reviewer)
- II. Peer Reviewers Input on Priority Items from CEC/ARB's Point of View
 - Treatment of GHG Emissions focusing on the Well-To-Tank evaluation
 - Vehicle Energy Consumption
 - Agricultural impacts related to ethanol and biodiesel production
 - Electric Power Generation (emissions related to electric drives)
 - Petroleum refinery impacts
- III. Other important FFCA areas TIAX wants the Peer Reviewers to address
 - General modeling approach
 - TIAX's Post Processor use in the FFCA
 - Treatment and presentation of the FFCA assumptions
 - Miscellaneous
- IV. Questions to Peer Reviewers from other meeting participants
- V. Next steps